Lasers in Surgery and Medicine 20:51–55 (1997)

Nd:YAG Laser and Tracheobronchial Metallic Stents: An Experimental In Vitro Study

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Study Design/Materials and Methods: **The aim of this experimental study was to investigate the effect of Nd:YAG laser on metallic trachebronchial stents, because Nd:YAG laser could be used for resection of tumourous tissue growing through stent meshes (Strecker-, Palmaz-, Wallstent).**
Study Design/Materials and Methods: **An in vitro worst-case-model was used to investigate the effects of different types of laser application on metallic stents: non-contact application, and contact application with bare fibres and with hemispherical sapphires.**
Results: **In the non-contact method and with bare fibres stent destruction occurred at power settings exceeding 10 W, whereas in the contact method with hemispherical sapphires power settings of 20 W were possible without stent damage. Lasers Surg Med 20:51–55, 1997.**

Key words: **contact laser; non-contact laser; sapphire tip; Palmaz-stent; Strecker-stent; Wallstent**

INTRODUCTION

Metallic stents have been successfully employed in tumourous tracheobronchial stenoses. One of the major drawbacks is the risk of tumour growth through the stent into the airway lumen if tumour-specific therapy does not follow. It leads to re-obstruction and necessitates stent removal in the majority of cases with all inherent inconveniences (e.g., pulmonary hemorrhage, severe dyspnea).

The aim of this experimental study was to investigate whether Neodynium:YAG laser can be used for recanalization without destruction of metallic stents. We used quartz fibres in the non-contact method [6–8] and both sapphire probes and bare fibres in the contact method. Until now sapphire tips have been successfully employed in laser angioplasty and gastroenterology [9–12]. Bare fibres in the contact method have mostly been used in surgery or gynecology [13–16].

MATERIALS AND METHODS

An in vitro "worst-case-model" was developed. We decided to use an inverse model with biological tissue (pork) inside the dilated stent forming a kind of cylinder (Fig. 1). This cylinder was coaxially pierced by a stiff wire to fix its horizontal position inside the testing installation. The laser fibre was perpendicular to the stent cylinder (Fig. 2). Stable temperature (37°C) and humification was ensured during the experiments.

In this study we used a Neodynium-YAG laser (fibertom 4060, Dornier, Munich Germany), wavelength 1,064 nm. The experiments were done with Strecker-, Palmaz-, and Wallstents.

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Accepted for publication 20 December 1995.

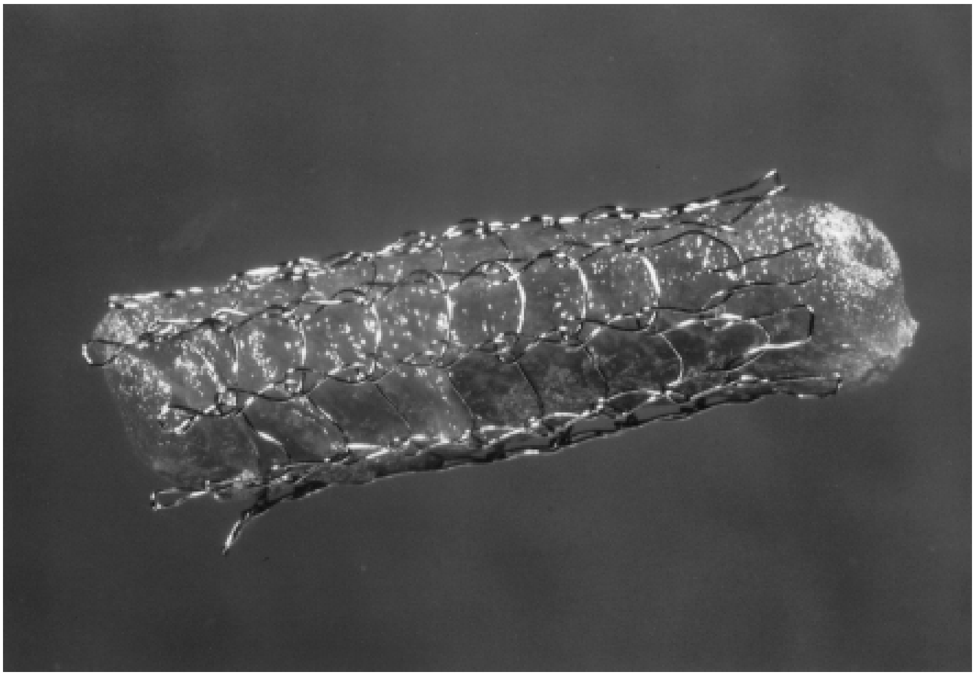

Fig. 1. Inverse Model with with biological tissue (pork) inside the dilated stent (Strecker-stent).

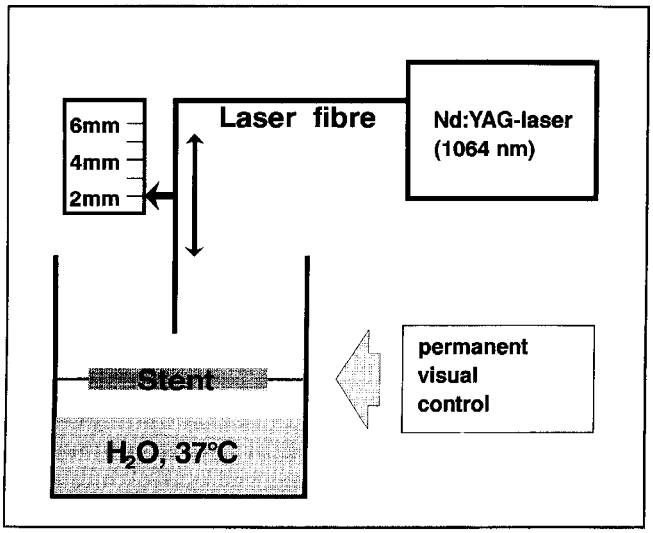

Fig. 2. The inverse model fixed inside the testing installation.

Non-Contact Nd:YAG-Laser Application

We used normal 400-µm quartz fibres (Dornier, Munich, Germany) cooled with air (flow 600 ml/min) for the non-contact experiments. The distance between stent and laser tip was measured by a metric scale in the testing installation.

Contact Nd:YAG-Laser Application

Contact application with bare fibres and hemispherical sapphire tips (MBB, Munich, Germany) was done with 600-µm fibres. The sapphire was screwed onto a metal connector attached to the catheter. It was not in contact with the fibre in order to avoid excessive heating. Saline was used as cooling medium (flow 10 ml/min). It reduces refraction between the end of the fibre and the artificial sapphire.

Procedure

The laser beam was administered to a single point with defined power setting, impulse frequency (12/min), and impulse duration (1.0 s). The maximum delivered dose was 500 J if the stent was not destroyed before. Every experiment was done ten times with the same setting.

In the non-contact experiments the distance between laser fibre and stent was 2 mm, 4 mm, and 6 mm. Power setting ranged from 10 W to 25 W.

In contact experiments power setting ranged from 20 W to 45 W. Sapphire tip and bare fibre touched the stent without pressure.

The testing installation allowed permanent visual control of the stent condition. Microscopic control was performed to detect small alterations of the stent material. The stent was judged destroyed when continuity of stent material was damaged or when the stent broke under light mechanical strain when the fibre was pressed against the stent.

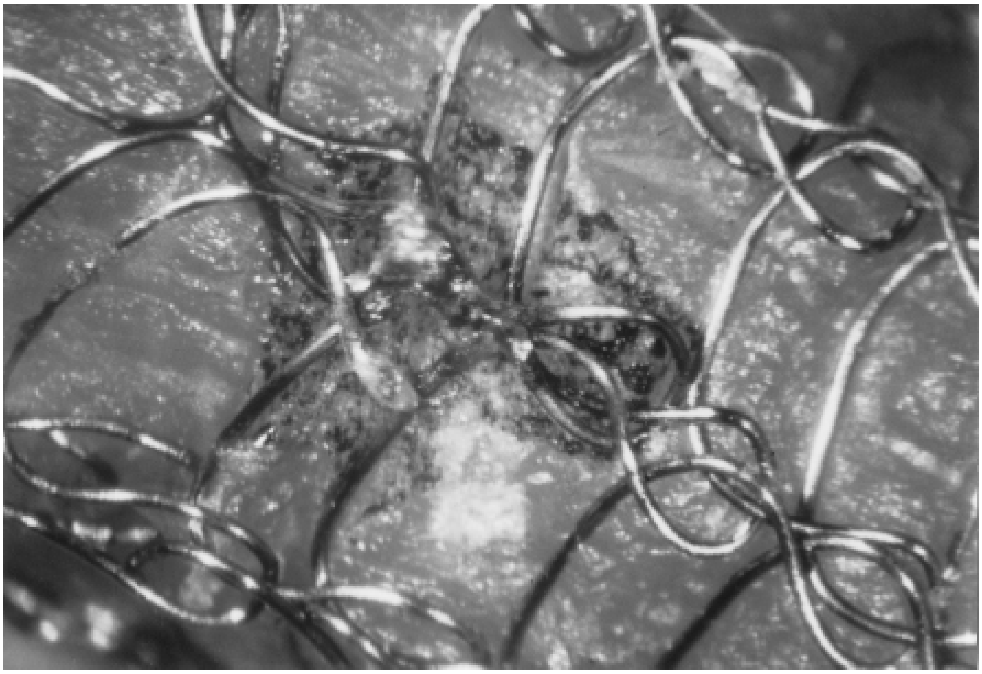

Fig. 3. Strecker-Stent after laser irradiation 2 × 10 W, distance 2 mm.

RESULTS

Non-Contact Nd:YAG Laser Application

The results of non-contact application are shown in Table 1. On the one hand energy which can be applied without stent destruction increases with the distance between laser fibre and stent. Stent destruction occurred at a power setting of 10 W when distance between laser fibre and stent was 2 mm (Fig. 3). At a distance of 6 mm the power setting of 10 W could be used without stent damage. On the other hand this energy decreases with the increase of power setting. This is valid also for the contact application.

The results do not show any significant difference between the stent types used.

Contact Nd:YAG Laser Application With Bare Fibres

The results of contact application with bare fibres are shown in Table 2. Stents were destroyed in most experiments when power setting was 15 W or more. The effects of laser irradiation with bare fibres (in contact) changed with the use of the fibre. Once the fibre had caused stent destruction at a power setting of, e.g., 20 W, it damaged the stent even at a power setting of 10 W, which was not the case before. The experiments were done with Strecker-stents only.

Contact Nd:YAG Laser Application With Hemispherical Sapphire Probes

The results of contact application with hemispherical sapphire tips are shown in Table 3. At a power setting of 20 W no stent destruction was observed. At 25 W and 30 W only Wallstents were destroyed, and when power setting exceeded 35 W, Strecker- and Palmaz-stents were also damaged.

It should be noted that at power settings over 30 W, the hemispherical sapphire tips cracked three times. After this damage, sapphire transmission was reduced in a way that the tips could not be used any further.

DISCUSSION

We investigated whether Nd:YAG laser can be used inside implanted metallic stents. The inverse model was chosen because of technical reasons (determination of the angle, visual control). It seemed to be an appropriate approximation to the in vivo situation. According to the experiences of others we believe that tissue perfusion has little effect upon laser lesions [17].

Non-contact experiments showed that laser energy is able to destroy metallic stents even at power settings of 10 W. We therefore feel that the

TABLE 1. Maximum Laser Irradiation in the Non-Contact Application Until Stent Destruction (Mean Values in Joules)†

Distance [mm]	Stent-type	Power setting 10 W	15 W	20 W	25 W
2	Wallstent	34,0 (±5.2) J	*	*	*
	Strecker	17,0 (±8.2) J	*	*	*
	Palmaz	20,0 (±8.2) J	*	*	*
4	Wallstent	>500 J	34,5 (±24.6)J	*	*
	Strecker	200 (±41.0) J	33,0 (±6.3) J	*	*
	Palmaz	146 (±37.2) J	42,0 (±6.3) J	*	*
6	Wallstent	>500 J	>500 J	66,7 (±30.1) J	*
	Strecker	>500 J	190 (±95.6) J	50,0 (±10.5) J	40,0 (±17.5) J
	Palmaz	>500 J	130,5 (±112.3) J	66,0 (±38.9) J	30,0 (±10.5) J

†Single impulse = 1.0 s; frequency (impulses/min) = 12/min.
*Stent destroyed after first impulse.

TABLE 2. Maximum Laser Irradiation in the Contact Application With Bare Fibres Until Stent Destruction (Mean Values in Joules)†

Stent-type	Power setting 10 W	15 W	20 W	25 W	30 W
Strecker	>500 J	52,5 (±46.1) J	24,0 (±8.4) J	*	*

†Single impulse = 1.0s; frequency (impulses/min) = 12/min.
*Stent destroyed after first impulse.

TABLE 3. Maximum Laser Irradiation in the Contact Application With Hemispherical Sapphire Tips Until Stent Destruction (Mean Values in Joules)†

Stent-type	Power setting 20 W	25 W	30 W	35 W	40 W	45 W
Wallstent	>500 J	205 (±143) J	167 (±92) J	*	*	*
Strecker	>500 J	>500 J	>500 J	>500 J	200 (±124) J	157 (±64) J
Palmaz	>500 J	>500 J	>500 J	150 (±72) J	64 (±28) J	*

†Single impulse = 1.0 s; frequency (impulses/min) = 12/min.
*Stent destroyed after first impulse.

Nd:YAG laser must not be used with power setting exceeding 10 W and distance should be at least 6 mm. As it is almost impossible to verify the distance between laser tip and tissue/stent under bronchoscopic conditions, it will be difficult to employ the restrictions given above. We therefore suggest that the use of Nd:YAG-laser under non-contact conditions inside metallic stents is not acceptable and leads to destruction of metallic stents.

Experiments with bare fibres in the contact method with saline cooling showed similar results as the non-contact application. The slightly higher power settings which could be used without stent damage can probably be attributed to the saline cooling. As properties of the bare fibre tips changed very much while they are used, we feel that their use inside metallic stents is not safe.

The experiments with contact sapphire probes showed that power settings of up to 20 W for Wallstents or 30 W for Strecker- and Palmaz-stents are possible without stent destruction. But one has to know that the laser effects are different from those achieved with non-contact laser application. There is less carbonisation, resulting in lower surface absorption and higher depth of penetration.

CONCLUSIONS

1. The Nd:YAG laser should not be used in the non-contact method for resection of tumourous tissue growing through the meshes of endo-

bronchial metallic stents because of a high risk of stent destruction.

2. The Nd:YAG laser should not be used in the contact method with bare fibres inside metallic stents.
3. The Nd:YAG laser in the contact method with hemispherical sapphire tips (saline cooling) demonstrated the best results in terms of prevention of stent destruction with maximum power settings of 20 W (30 W for Strecker and Palmaz-stents). Further clinical investigations are warranted to prove whether the promising results of our in vitro studies comply with clinical reality.

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